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(54) **Durable, lightweight, radar lens antenna**

**Dauerhafte, leichte Radar-Linsen-Antenne**

**Antenne de radar légère et durable à lentille**

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## Description

### Background of the Invention

[0001] The present invention relates to radar antennas, and has particular relation to radar antennas which function as a radome and also function as lenses to focus the radiation which passes through them.

[0002] When a radar is used on an automobile, it must meet the road driving environment by having a radome which will protect the radar from road debris as well as from air. It is desirable for the radome to also perform a focusing function for the antenna. A conventional radome durable enough to provide such service has generally been considered to be unsuitable for even semi-precise focusing.

[0003] Scanning an antenna beam rapidly with a lens antenna is usually achieved by electronically switching between multiple feed horns. However, it becomes impractical to do this in most missile sensor applications. Producing an adequate scan field of view results in unacceptably high insertion losses of the series connecting switches. It also results in unacceptably high antenna side lobe levels for far out, off axis beams.

[0004] Scanning can be accomplished by moving a durable, lightweight antenna lens back and forth in front of a fixed antenna feed. However, the speed of scanning is inversely proportional to the weight of the lens, and prior art radomes are also heavy. Fortunately, lightness and durability may be traded off with each other. If a moderate weight lens of considerable durability is placed in a protected environment, it can easily be modified to be less durable, but very light. The forward end of a missile, behind a separate radome, is such a protected environment.

### Summary of the Invention

[0005] The present invention overcomes these deficiencies by modifying a conventional Fresnel lens design. The conventional curved lens surface is replaced with steps approximating it, preferably three steps. The thickness of the stepped lens, at each step, is a half-wavelength or a multiple half-wavelength of the radar operating frequency in the medium of the lens. The half-wavelength or multiple half-wavelength separation of the steps causes reflections from the front and rear surfaces to cancel. This provides a nearly perfect impedance match, thereby minimizing the (undesirable) standing wave between the lens and the feed horn. This thereby further avoids the necessity of using other standing wave reduction methods, such as (a) coating one or both surfaces with an antireflection coating, or (b) presenting the curved or stepped side forward to avoid focusing of reflected signals at the antenna feed. Coatings are expensive, and the planar side of the lens (unlike the stepped side) doesn't need to be protected from road debris. The lens and radome can therefore

be molded as an integral unit, desirable in the automotive setting.

[0006] This lens is also thin enough (and, therefore, light enough) that it can be moved side-to-side very rapidly, preferably by a combination of cams and springs. This allows a very fast scan, albeit over a limited field of view. Gimbaling the lens and feed horn together provides a slower scan, but gives an unlimited field of regard. Combining the two gives a fast scan and unlimited regard, desirable in the missile setting.

### Brief Description of the Drawings

[0007] Figure 1 shows the contour of a Fresnel lens in three embodiments: full zone 10; partial zone 12; and step zone 14.

[0008] Figure 2 shows the details of the step zone lens 14.

[0009] Figure 3 shows the lens 14 in operation, refracting radar signals both directly from the feed horn or feed horns 46, 48, 50 and indirectly from an enclosing housing 40.

[0010] Figure 4 shows the lens 14 being moved perpendicular to the beam of radiation through it, thereby changing the beam's direction.

[0011] Figure 5 shows gimbaling 56 the lens 14 and feed horn or feed horns 46, 48, 50 together.

### Detailed Description of the Drawings

[0012] In Figure 1, a lens 14 is made of a material, preferably a plastic which has a suitable index of refraction to electromagnetic radiation of a desired frequency, and which is hard and strong. The plastic sold under the trade name LEXAN has the desired electrical and mechanical properties, and is preferred.

[0013] The lens 14 has a front surface 16 and a rear surface 18, the front surface 16 being planar. The rear surface 18 includes a plurality of stepped Fresnel zones 20. Each stepped Fresnel zone 20 consists essentially of a plurality of steps 22, 24, 26, preferably three. Each step 22, 24, 26 is parallel to, and lies a fixed distance from, the front surface 16.

[0014] Figure 2 shows each stepped Fresnel zone 20 corresponding to a conceptual, similarly refractive, conventional Fresnel zone 28. That is, to determine the location of each step of each stepped Fresnel zone 20 on the rear surface 18 of the actual lens 14, first determine its distance  $d$  from its front surface 20. Then look to a conceptual, conventional Fresnel lens 10, one which is similarly refractive. It also will be broken up into a like number of zones 28 on its rear surface 30. Find the location of the portion 32 of the corresponding, conventional, zone 28 which is the same distance  $d$  from its front surface 30. This is where the step 22, 24, 26 should be located.

[0015] Figure 3 shows the lens 14 being driven by a source 34 of electromagnetic radiation 36 of the desired

frequency. This source is preferably located at a tapered end 38 of a tapering enclosure 40 which faces the rear surface 18 of the lens 14. The tapering enclosure 40 may be conductive or radio-frequency absorptive, as desired.

[0016] In Figures 1 and 2, the distance  $d$  to each step 22, 24, 26 from the front surface 16 is an integral multiple of half the wavelength ( $\lambda_g$ ) at the desired frequency. This allows reflections from the front and rear surfaces 16, 18, 22, 24, 26 to cancel. This cancellation reduces or eliminates standing waves within the enclosure 40.

[0017] Figure 4 shows the lens 14 being moved perpendicular to the beam of radiation through it, thereby changing the beam's direction. The lens 14, being so thin, is very light, and may therefore easily be moved in a direction parallel to its front surface 16 by any suitable means. The preferred moving means is a cam 42 on one side of the lens 14 and a spring 44 on the opposite side. Moving the lens 14 perpendicular to the radiation 36 changes the direction of the beam emerging from the lens 14, and is much easier than attempting to move the feed horn, or other source 34 of electromagnetic radiation. This motion allows fine control over the beam's direction. Gross motion may be provided, if desired, by a plurality of feed horns 46, 48, 50 at the tapered end 38 of the enclosure 40. Since each feed horn 46, 48, 50 lies at a slightly different position, each produces a beam which emerges from the lens 14 in a slightly different direction. Gross motion may also be provided by gimballing the entire apparatus.

[0018] First and second moving means for moving the lens 14 in first and second directions parallel to its front surface 16, and perpendicular to each other, may be provided. As before, the preferred moving means in both directions is a cam 42, 52 on one side of the lens 14 and a spring 44, 54 on the opposite side.

[0019] Figure 5 shows gimballing 56 the lens 14 and feed horn or feed horns 46, 48, 50 together.

## Claims

1. A lens comprising a material, wherein:

- (a) the material has an index of refraction to electromagnetic radiation at a desired frequency;
- (b) the index of refraction produces, within the material, a desired wavelength of the electromagnetic radiation at the desired frequency;
- (c) the material has a front surface and a rear surface;
- (d) the front surface is planar;
- (e) the rear surface includes a plurality of stepped Fresnel zones;
- (f) each stepped Fresnel zone consists essentially of a plurality of steps;
- (g) each step is parallel to, and has a fixed dis-

tance from, the front surface; and  
(h) the distance to each step from the front surface is an integral multiple of half the wavelength at the desired frequency, measured in the material of which the lens is comprised.

- 2. The lens of claim 1, wherein each Fresnel zone has three steps.
- 3. The lens of claim 1, further comprising a tapering enclosure facing the rear surface of the lens.
- 4. The lens of claim 3, wherein the tapering enclosure is conductive.
- 5. The lens of claim 3, wherein the tapering enclosure is radio-frequency absorptive.
- 6. The lens of claim 3, further comprising a source of electromagnetic radiation of the desired frequency located at a tapered end of the tapering enclosure.
- 7. The lens of claim 1, further comprising a moving means for moving the lens in a direction parallel to the front surface of the lens.
- 8. The lens of claim 7, wherein the moving means comprises a cam on one side of the lens and a spring on an opposite side of the lens.
- 9. The lens of claim 1, further comprising:
  - (a) a first moving means for moving the lens in a first direction parallel to the front surface of the lens; and
  - (b) a second moving means for moving the lens in a second direction parallel to the front surface of the lens and perpendicular to the first directions and/or

wherein preferably each moving means comprises a cam on one side of the lens and a spring on an opposite side of the lens.

10. A lens comprising according to claim 1 wherein:

- (f) each stepped Fresnel zone corresponds to a conceptual, similarly refractive, conventional Fresnel zone and wherein
- (i) each step of each stepped Fresnel zone has a location on the rear surface which is the same as the location on the rear surface of a portion of the corresponding conceptual, similarly refractive, conventional Fresnel zone, said portion of the conventional Fresnel zone having the same distance from the front surface as the step of the stepped Fresnel zone.



## Patentansprüche

1. Eine Linse die ein Material aufweist, wobei:
  - (a) das Material einen Brechungsindex für elektromagnetische Strahlung bei einer gewünschten Frequenz aufweist; 5
  - (b) der Brechungsindex innerhalb des Materials eine gewünschte Wellenlänge der elektromagnetischen Strahlung mit der gewünschten Frequenz erzeugt; 10
  - (c) das Material eine vordere Oberfläche und eine hintere Oberfläche besitzt;
  - (d) die vordere Oberfläche planar (eben) ist;
  - (e) die hintere Oberfläche eine Vielzahl von gestuften Fresnel-Zonen aufweist; 15
  - (f) wobei jede gestufte Fresnel-Zone im Wesentlichen aus einer Vielzahl von Stufen besteht;
  - (g) jede Stufe parallel ist zu und einen festen Abstand hat von der vorderen Oberfläche; und 20
  - (h) der Abstand zu jeder Stufe von der vorderen Oberfläche ein ganzzahliges Vielfaches der Hälfte der Wellenlänge bei der gewünschten Frequenz ist, und zwar gemessen in dem Material aus dem die Linse besteht oder aufgebaut ist. 25
2. Linse nach Anspruch 1, wobei jede Fresnel-Zone drei Stufen besitzt. 30
3. Linse nach Anspruch 1, wobei ferner eine sich verjüngende Umschließung vorgesehen ist, die zur hinteren Oberfläche der Linse hinweist. 35
4. Linse nach Anspruch 3, wobei die verjüngende Umschließung leitend ist.
5. Linse nach Anspruch 3, wobei die verjüngende Umschließung Hochfrequenz absorbiert. 40
6. Linse nach Anspruch 3, wobei eine Quelle elektromagnetischer Strahlung mit der gewünschten oder Sollfrequenz vorgesehen ist, und zwar angeordnet an einem verjüngten Ende der sich verjüngenden Umschließung. 45
7. Linse nach Anspruch 1, wobei ferner Bewegungsmittel vorgesehen sind zur Bewegung der Linse in einer Richtung parallel zur vorderen Oberfläche der Linse. 50
8. Linse nach Anspruch 7, wobei die Bewegungsmittel einen Nocken auf einer Seite der Linse aufweisen und eine Feder auf einer entgegengesetzten Seite der Linse. 55
9. Linse nach Anspruch 1, wobei ferner folgendes vor-

gesehen ist:

- (a) erste Bewegungsmittel zur Bewegung der Linse in einer ersten Richtung parallel zur vorderen Oberfläche der Linse; und
  - (b) zweite Bewegungsmittel zur Bewegung der Linse in einer zweiten Richtung parallel zur vorderen Oberfläche der Linse und senkrecht zur ersten Richtung, und/oder wobei vorzugsweise jedes der Bewegungsmittel einen Nocken auf einer Seite der Linse und eine Feder auf einer entgegengesetzten Seite der Linse aufweisen.
10. Eine Linse nach Anspruch 1, wobei
- (f) jede gestufte oder abgestufte Fresnel-Zone einer konzeptionell ähnlich bzw. in gleicher Weise brechenden konventionellen Fresnel-Zone entspricht, und wobei
  - (i) jede Stufe jeder abgestuften Fresnel-Zone eine Stelle auf der hinteren Oberfläche aufweist, die die gleiche ist wie die Stelle an der hinteren Oberfläche eines Teils der entsprechenden konzeptionellen ähnlich oder gleich brechenden konventionellen Fresnel-Zone, wobei der erwähnte Teil der konventionellen Fresnel-Zone den gleichen Abstand von der vorderen Oberfläche besitzt, wie die Stufe der abgestuften Fresnel-Zone.

## Revendications

1. Lentille comprenant un matériau dans laquelle :
  - le matériau présente un indice de réfraction à la radiation électromagnétique à une fréquence de consigne ;
  - l'indice de réfraction produit, au sein du matériau, une longueur d'onde de consigne de radiation électromagnétique à une fréquence de consigne ;
  - le matériau présente une surface antérieure et une surface postérieure ;
  - la surface antérieure est plane ;
  - la surface postérieure comprend une pluralité de zones de Fresnel à échelons ;
  - chaque zone de Fresnel à échelons consiste essentiellement en une pluralité des échelons ;
  - chaque échelon est parallèle à la surface antérieure et à une distance fixe de celle-ci ; et
  - la distance de chaque échelon de la surface antérieure est un multiple entier de la demi longueur d'onde à la fréquence de consigne, mesurée dans le matériau dont la lentille est composée.
2. Lentille selon la revendication 1, dans laquelle cha-

que zone de Fresnel présente trois échelons.

la zone de Fresnel à échelons.

3. Lentille selon la revendication 1, comprenant en outre une enceinte conique faisant face à la surface postérieure de la lentille. 5
4. Lentille selon la revendication 3, dans laquelle l'enceinte conique est conductrice.
5. La lentille selon la revendication 3, dans laquelle l'enceinte conique absorbe les fréquences radio. 10
6. Lentille selon la revendication 3, comprenant en outre une source de radiation électromagnétique de la fréquence de consigne située à une extrémité conique de l'enceinte conique. 15
7. Lentille selon la revendication 1, comprenant en outre des moyens de déplacement pour déplacer la lentille dans une direction parallèle à la surface antérieure de la lentille. 20
8. Lentille selon la revendication 7, dans laquelle les moyens de déplacement comprennent une came sur un côté de la lentille et un ressort à un côté opposé de la lentille. 25
9. Lentille selon la revendication 1, comprenant en outre : 30
  - des premiers moyens de déplacement pour déplacer la lentille dans une première direction parallèle à la surface antérieure de la lentille ; et
  - des seconds moyens de déplacement pour déplacer la lentille dans une seconde direction parallèle à la surface antérieure de la lentille et perpendiculaire à la première direction, et/ou dans lesquels de préférence chaque moyen de déplacement comprend une came sur un côté de la lentille et un ressort sur un côté opposé de la lentille. 35 40
10. Lentille selon la revendication 1, dans laquelle : 45
  - chaque zone de Fresnel à échelons correspond à une zone de Fresnel classique, de réfraction similaire et conceptuelle et dans laquelle : 50
    - chaque échelon de chaque zone de Fresnel à échelons se trouve à un emplacement sur la surface postérieure qui est identique à l'emplacement sur la surface postérieure à une partie de la zone de Fresnel classique de réfraction similaire et conceptuelle, la dite partie de la zone de Fresnel classique ayant la même distance de la surface antérieure que l'échelon de 55

# ZONED LENS DESIGN OPTIONS

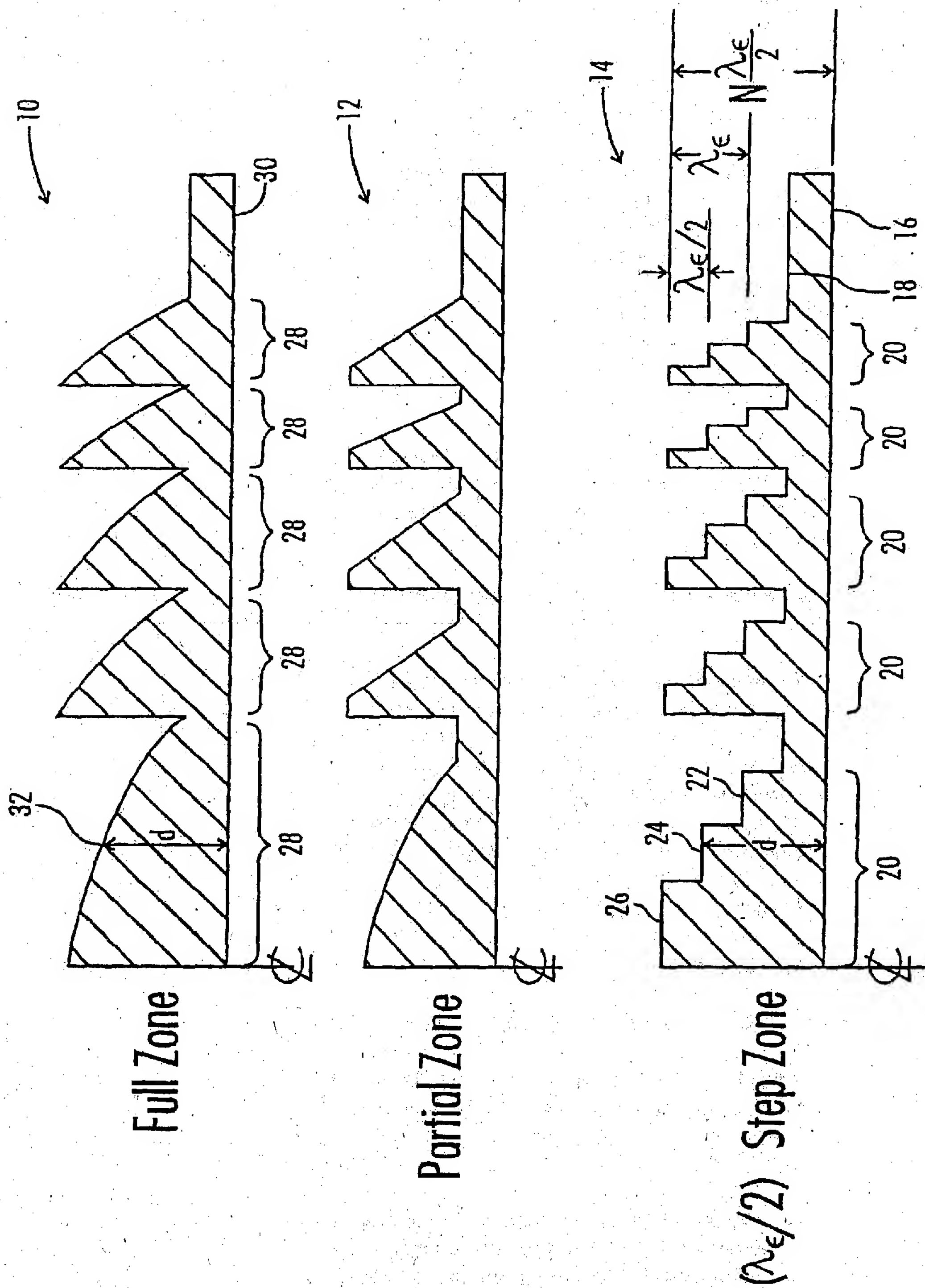


FIG. 1

Three ( $\lambda_e/2$ ) Step Zone

Zoned Lens  
Aperture Phase

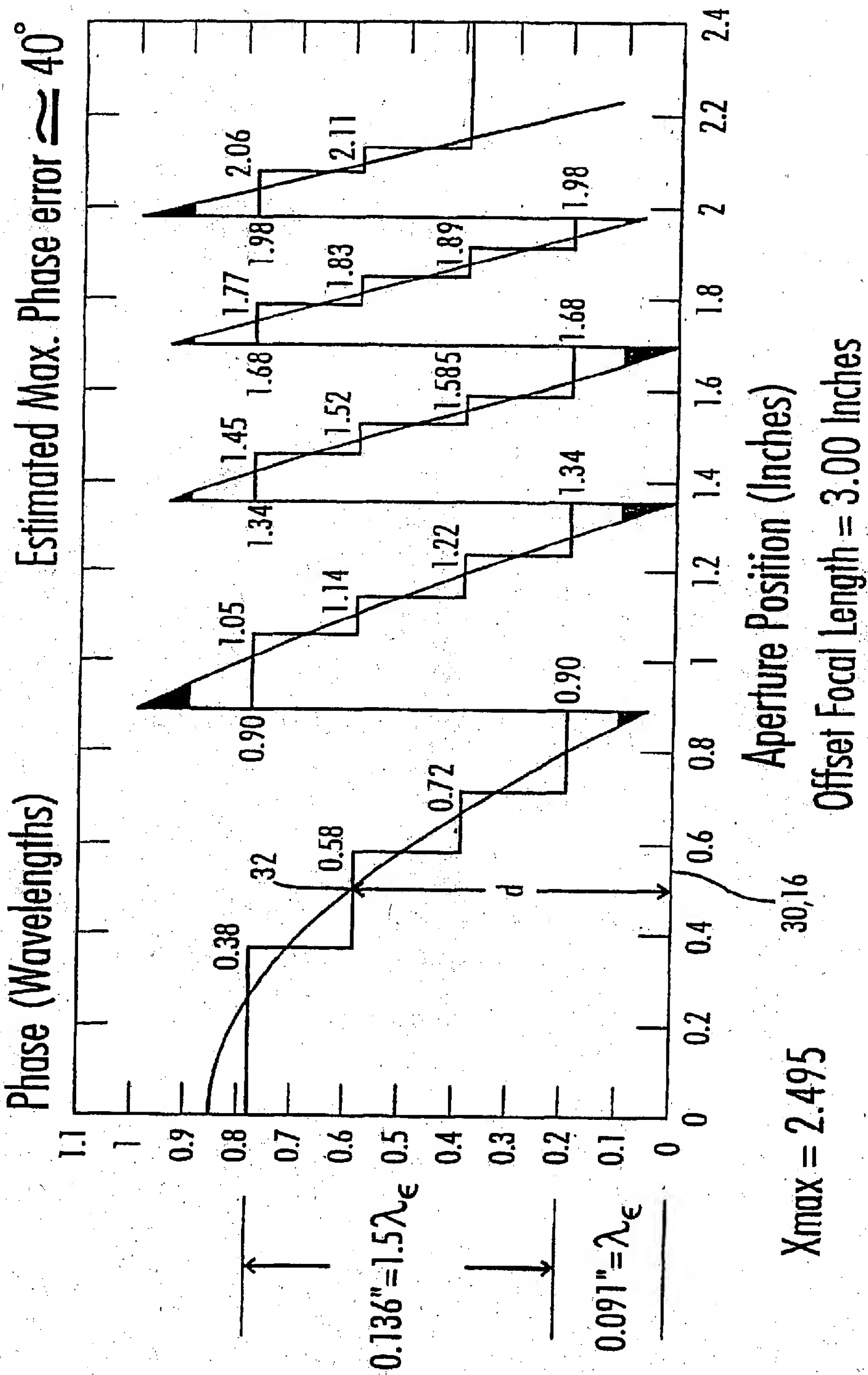


FIG. 2

# RADLANT (RADome Lens ANTenna)

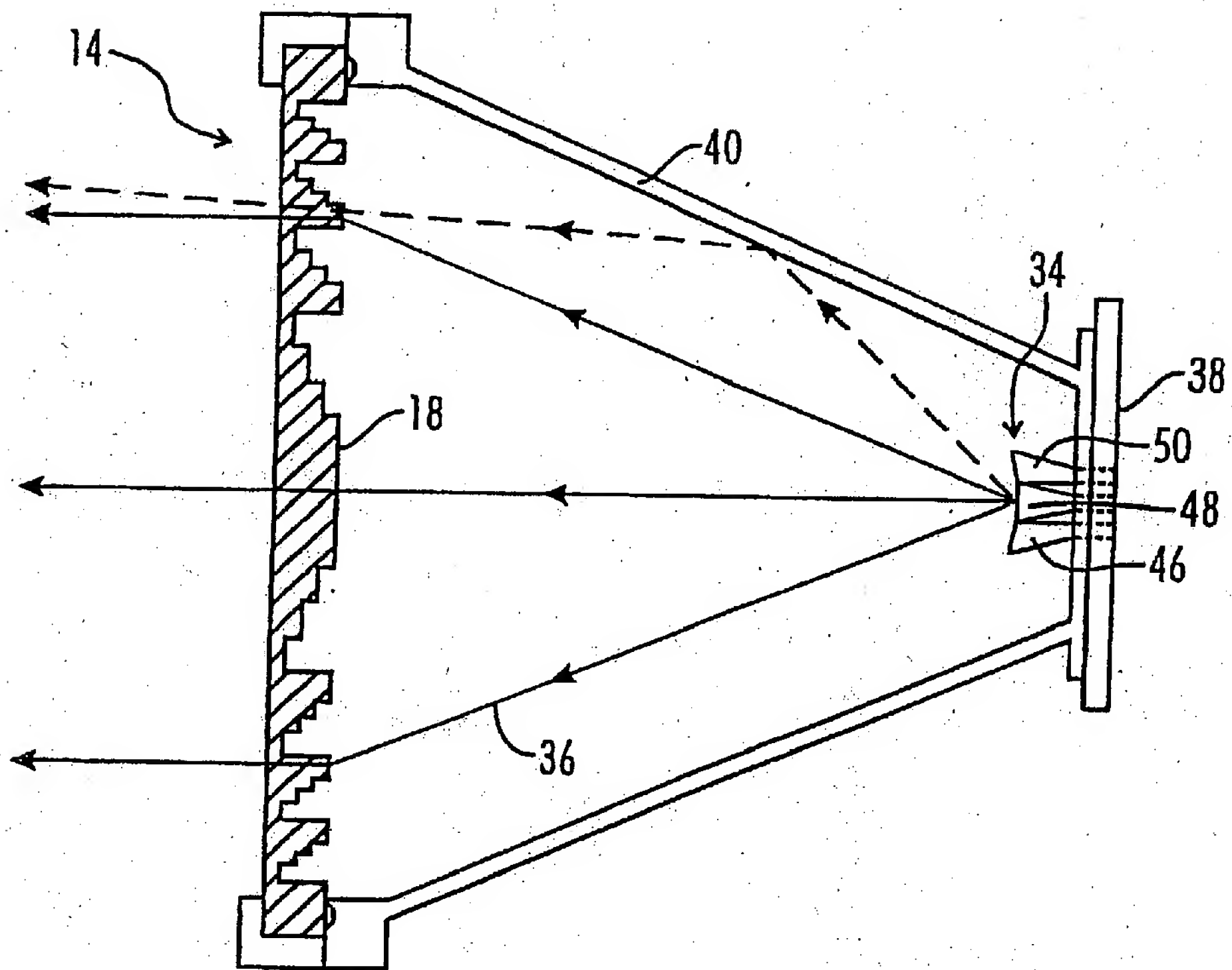
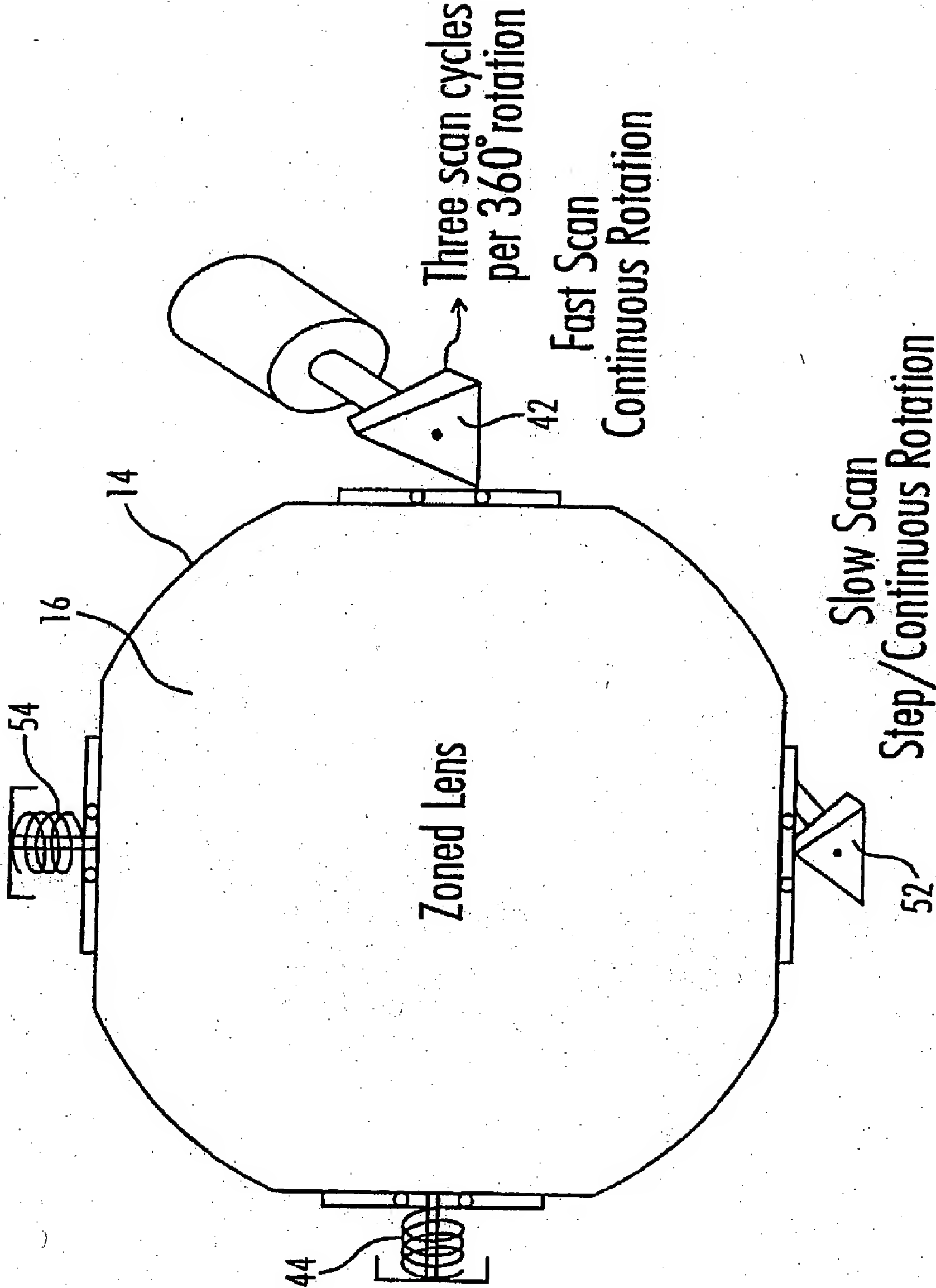


FIG. 3



Two Axes  
Rapid Scan MMW Antenna for AGM-130



Lens Drive Mechanization

FIG. 4

# MMW Antenna For AGM-130 SAR

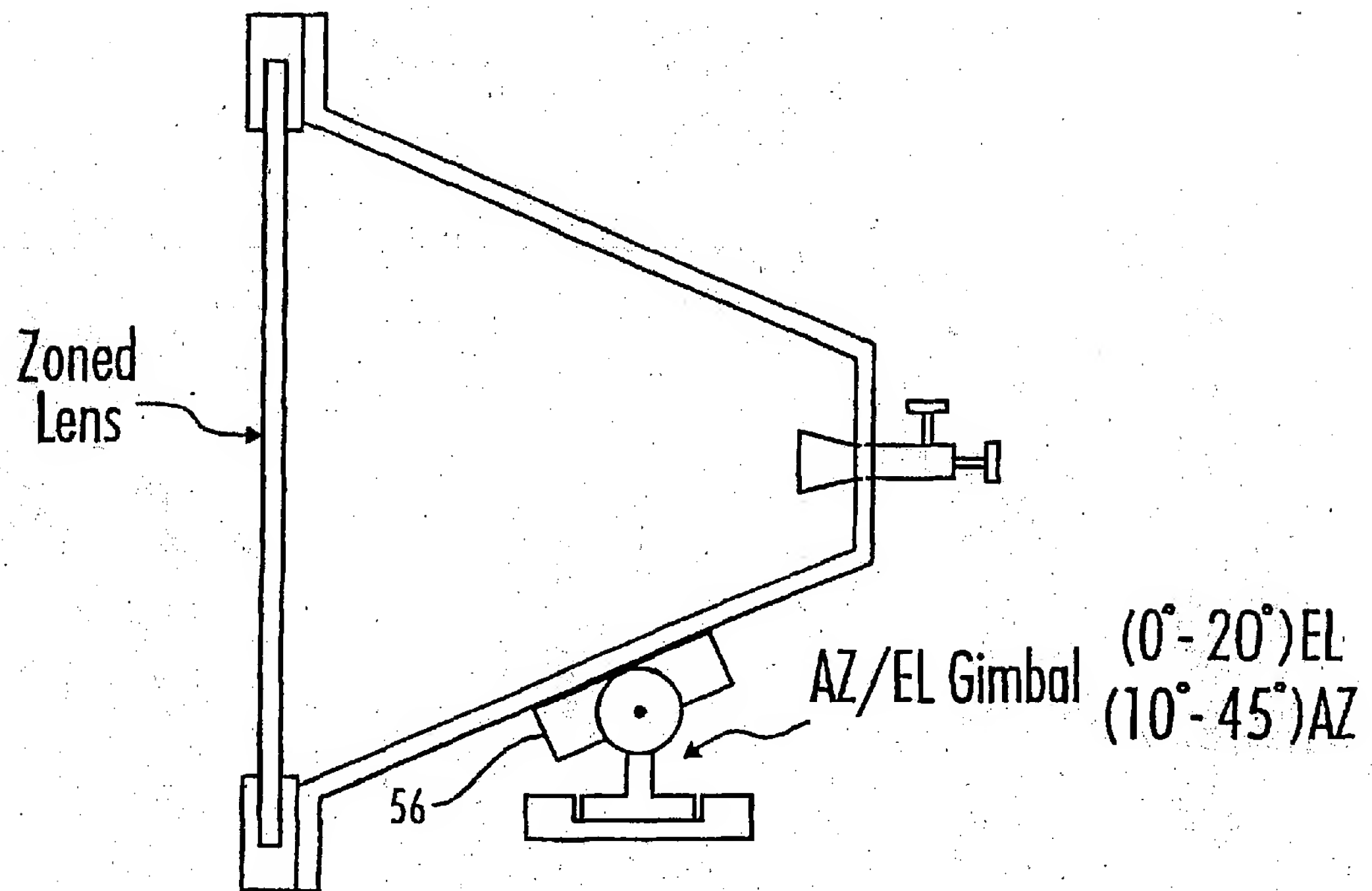


FIG. 5